

BOECKMANN (E.)

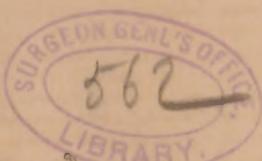


## Some Remarks About Asepsis in Military Service

BY LIEUT.-COL. EDUARD BOECKMANN,

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Reprint from the Proceedings  
of the Fifth Annual Meeting of the Military Surgeons of the United States,  
Buffalo, N. Y., May 21, 22 and 23, 1895.





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It is with some hesitancy that I venture to bring such a worn-out topic as asepsis before this distinguished assembly, which is represented by our foremost bacteriologists, our best surgeons, and by men who, perhaps, daily have opportunity to rejoice over the good fruits of their aseptic efforts; but, when I, at the same time, consider that the last word in asepsis has not yet by any means been spoken; that our views, in consequence, are subject to change, and our opinions vary; that there yet prevails considerable difference, and even uncertainty, with regard to the value of the different means and apparatus of disinfection; that daily, partly through ignorance and partly through negligence, violence is done to the simple, but strict, laws of asepsis, and that we, military surgeons, because of the peculiar and difficult conditions under which we must exercise the aseptic art, in service particularly, should be fully conversant with the principles of asepsis, I certainly need no apology for presenting that which at first sight appears to be A B C's to us all.

Our surgical enemies, which all of us know either through our practice or through books, and which are distinguished by their ubiquity and numerousness, less by their tenacity of life, we endeavor to keep at their distance in different ways—we destroy them, we remove them, or we render them innocuous. Could we simply destroy them all this would be the most ideal procedure, but since this, unfortunately, is impracticable, we must in every case avail ourselves not only of the thermic means of disinfection which are the proper germicides, but also of mechanical and chemical measures whose usefulness consists in the removal and the inhibition of growth of the micro-organisms.



*Mechanical Disinfection.*—Since we can not boil our hands, nor put our patients in a steam sterilizer, and since the chemical disinfectants can not sterilize an infected skin in such concentration as can be used in practice, and in such time as is at our disposal, it is clear, and universally conceded, that the crucial point in the sterilizing process of the operator's hands and the patient's field of operation must lie in the mechanical removal of the ever-present and innumerable micro-organisms in these situations. This can also essentially be accomplished by razor, nail-cleaner, water, soap, brush, and towel; but any absolute surgical sterilization is hardly within possibility, as the surgical micro-organisms are met with not only in the deeper epidermic layers but also in the different adnexa of the skin.

That disinfection which results from a careful mechanical treatment of the skin has been made fractional by different authors, some putting it at a half, others at two-thirds, while, as is well known, there are those who, both on this side and the other side of the Atlantic, find in the mechanical moment the ideal in surgical sterilization of the epidermis. In my opinion we can not well express in definite fractions the aseptic value of mechanical disinfection, since individual differences, in the first place, obtain in high degree, and since, in the second place, mechanical disinfection is an art exercised by different operators in extremely varying degrees of efficiency. It is, unfortunately, not to be denied that those operators who really understand how to wash themselves surgically still are in the minority, which is deplorable, as I am one of the many who, by experience, have arrived at the conclusion that mechanical disinfection can nearly approach surgical asepsis if practiced intelligently. We should certainly be spared the painful spectacle of seeing a surgeon omit to remove his finger-rings, and, at the same time, it is only a reasonable demand that the shirt sleeves be rolled up beyond the elbow. It is unquestionably proper to use a razor on the field of operation, not so much for the sake of the hair as for the skin, whose disinfection is thereby greatly facilitated. The surgeon himself, by right, does not shave his arms or hands, which would be a necessity if this process should be a *sine qua non* for the disinfection, as far as the hair is concerned. The washing itself must be performed in a routine manner; first, a general soaping and

scrubbing, thereupon a special ditto of each part. The extensor surface of the arms is reached by flexion, and not by extended pronation or supination; special attention is given the finger-ends, the nails, and the folds between the fingers. The more changes of water (preferably running and sterile), the higher the temperature (up to 120° F.), the cleaner the brush (best a stiff one), the purer the soap (boiled, green soap), and the longer time devoted, the better is naturally the result. It is certainly perfectly proper that we afterward wipe the thus-treated skin with a sterile towel, and when this is done we have, in all essentials, removed what, practically, is all-determining, and we can, as a rule, proceed to any operation whatever with a good conscience and justified hope for an aseptically good result, so far as the operator's hands, and the patient's field of operation, treated similarly, are concerned.

Yet it is necessary, beyond being a good washerwoman, to be both an able and experienced operator, in order to attain aseptically good results from the mechanical disinfection, and as it falls to the lot of comparatively few to become at the same time able and experienced surgeons, it is advisable for those who are not specialists that they not only extend the traditional one minute, but that they add something more. It is customary to scrub the skin with strong alcohol, ether, or turpentine after the thorough washing with soap; the method is certainly justified, as the named articles are of recognized value in the removal of grease spots. To be sure, we advance a step further by an energetic scrubbing with one of these agents, followed by drying with a sterile towel. There are even those who consider alcohol omnipotent in the disinfection of the skin, and we can not very well contradict such a profanation; however, these strongly fat-dissolving agents make the skin dry and brittle (an unpleasant occurrence for sensitive skins); wherefore many, among them the author, have discontinued the use of alcohol, ether, and turpentine, and preferred to make the remaining micro-organisms innocuous by chemical agents, of which more below. By the mechanical disinfection we aim to the greatest possible extent to dissolve and remove the fatty skin-covering, rich in bacteria. This fat plays an important rôle in the economy of the skin; it is to keep it pliable and elastic; it is to receive and arrest, and thus prevent the innumerable bacteria which come in contact with it from causing local or universal

trouble; therefore, it appears to me proper to restore to the skin that protective we have endeavored to deprive it of, in the form of a sterile fat, not only for the sake of the skin, but also to cover up and arrest the remaining bacteria, and thereby prevent them from infecting the operation-wound. The idea is not new, but is, for the time being, hardly realized beyond examinations and operations upon the vagina and rectum. I believe that this method has quite a future in surgery generally, if we employ a material of the same composition or quality as that which is found upon our skin. Lanolin is the fat which I have used for this purpose during the past year, and provisionally I have every reason to be satisfied therewith. Lanolin is, as known, a product of sheep's wool; it does not saponify or become rancid, has a remarkable penetrating power, and sticks excellently to the skin. Lanolin absorbs water greedily, and the commercial article contains about twenty-five per cent; this is called simply lanolin, and forms an almost white salve-like mass, while the dehydrated lanolin (lanolinum anhydridum) looks like honey, and is of the consistency of vaseline. Pure lanolin is without smell or taste; anhydrous lanolin is simply sterilized by boiling; it boils at a temperature of about 400 degrees F., a temperature which instantly destroys all bacterial life. Ordinary lanolin can not be sterilized in this manner, as the contained water will be separated and, in boiling, cause the lanolin to be thrown to all sides; it must first be dehydrated, which is fairly accomplished by heating in a steam sterilizer for some time, after which it is set away to be cooled; the water will accumulate below, while the anhydrous lanolin will solidify above. When this has occurred a hole is made through the lanolin and the water emptied, after which the lanolin is carefully heated up to its boiling point over a weak flame; it is now surgically sterile.

A convenient mode of keeping sterile lanolin ready for use is to pour some into a sterile flask with glass stopper, and add to it four or five times the volume of anhydrous ether, which keeps the lanolin dissolved. If a little of this solution is poured into the hands a few moments suffice to rub it well into the skin; the ether evaporates quickly, and the lanolin remains. Another, in military service, convenient method is to run the lanolin, while melted, into collapsible tubes, such as painters use, sterilized beforehand by boiling. A small amount is pressed out and well rubbed into the skin, where-

after the excess is removed by a sterile towel and pressing out from under the finger-nails.

*Chemical Disinfection.*— After having softened up and removed the epidermic dirt mechanically, it is a standing rule to wash or scrub the skin with corrosive sublimate solution, to destroy the bacteria which have not been and can not be removed; theoretically, no criticism can be made against this practice; practically, I am strongly inclined to believe that the whole is a comedy of errors. It is not denied that corrosive sublimate is chemically the most powerful germicide at our disposal, but Geppert's well-known experiments, which have been corroborated by later investigators (Abbott and others), have long ago proven that it not only requires a one-to-thousand solution a long time—hours—to kill surgical bacteria, but that the latter must be exposed in pure culture—conditions which rarely obtain in practical life—not even after the most thorough mechanical disinfection. Corrosive sublimate must form a chemical combination with the protoplasm of the bacterium in order to unfold its germicidal power, which does not occur when these are imbedded and hidden in fat, albuminous material, and dirt. It is an every-day occurrence to see how a sublimate solution rolls off the skin, like water on a duck's back, without the least impregnation; the result is in the main the same, when the skin is beforehand treated with warm water, brush, and soap, and even with alcohol. No name-worthy difference is to be remarked, even with the addition of tartaric acid to the sublimate. Even if, with an energetic brushing extending over minutes, we succeed in forcing some into the skin, this impregnation is always, in the first place, superficial, and in the second, the time is too short for any germicidal action; thereto is added the wiping or washing off of the excess sublimate, whereby we, through justified fear of toxic action, renounce the antiseptic rôle which these drops could play in the operation by inhibiting the growth of present germs. For these, and other reasons, I have entirely abandoned sublimate in the disinfection of my hands, while I still recognize its value at the field of operation, when we, as is the rule in civil practice, can expose this to its continued action in weak solution for a day or two. That the skin in this manner can be impregnated, and the bacteria killed or rendered innocuous, I see a proof of in the eczemas which arise, and in the cases of poisoning

which may be the result of these wet applications, and, at the same time, that cultures from scrapings of the epidermis are negative as a rule.

The English antiseptic—carbolic acid—is by far not as germicidal as sublimate, for which reason this agent for the same purpose is used in per cents, where sublimate is used in per mille, or fractions thereof; but carbolic acid has the undeniable and great advantage over sublimate that it penetrates the skin without previous preparation of the latter. Thereupon depends its antiseptic power, and consequently the danger of poisoning. Carbolic acid will not be able to kill anything in the short time, and in the strength, which is at our disposal; it has no justification as a germicide, an agent which annihilates the vitality of the organisms, but as an antiseptic, an agent which inhibits their growth without destroying their vitality. This last is sufficient for the purposes of the surgeon, since the phagocytes immediately begin their important scavenger work, and generally with decided success, when the number of dormant bacteria is small and the virulence moderate. Although sublimate, in a concentration of 1 to 300,000, inhibits the growth of micro-organisms, while carbolic acid requires a strength of 1 to 850 to accomplish the same, the last antiseptic is preferable for the reasons above given.

In the meantime carbolic acid possesses important disadvantages. Many surgeons can not use it because it causes annoying eczemas, or, in any event, dry and chapped hands, and anesthesia. Carbolic acid as an application on the skin, mucous membranes, or on wounds, is an exceedingly dangerous agent to the organism, and cases of poisoning have both been numerous, fatal, and often compromising; for these reasons I never could persuade myself to employ this chemical in disinfection of the skin, but have cast about for an agent that possesses the advantage, but not the drawbacks, of carbolic acid.

Such an one probably does not exist; I have provisionally availed myself of lysol, which possesses its good qualities in the same or higher degree, and its disadvantages in less. Lysol is saponified phenol, derived from cresol, a coal-tar product of superior antiseptic power to carbolic acid, by the action of nascent soap.

It is a good antiseptic in a strength of one to three per cent. Lysol is viscid, brown, and strongly alkaline; it dissolves readily in water,

which carbolic acid does not do; the solution foams like soap-water, penetrates the skin easier than carbolic acid, makes the skin soft and pliable, burns a little, and causes after a short time a feeling of slight numbness; its toxic properties are not as marked as carbolic. It is, on the whole, eminently qualified for washing the hands and the site of operation, whether the skin is broken or not, while continued wet applications have, to some extent, the disadvantages of carbolic acid with regard to burning and the production of eczema, for which reason I still prefer weak solutions of sublimate for this purpose. I believe that military surgeons should adopt this practical, inexpensive, and good preparation — which is at the same time both a soap and an antiseptic—as the disinfection of hands and field of operation, according to Fürbringer's method (warm water, soap, brush, nail cleaner, alcohol, sublimate, and sterile towel), always will be impracticable in actual service.

The disinfection which I will take the liberty to recommend in military service, as well as in civil, where circumstances admit of it, is as follows: Brush the hands intelligently in a quart of hot water with a clean, stiff brush, to which has been added, by guess, a tablespoonful of lysol; then clean the finger nails. Cleanse anew the hands with a fresh solution of lysol and a clean brush, and dry them afterward with a sterile towel, and rub thereafter the hands well with lanolin from the tube; remove the excess of lanolin. In the absence of hot water employ cold for a longer time; in the absence of water simply rub the hands with lanolin, which, under all circumstances, is better than nothing. The field of operation is treated in the same way.

It is within the possibility that it might be of value to render the lanolin antiseptic with lysol where we are prevented from using both separately. As is well known, the antiseptics certainly lose a good deal of their value by being mixed with fatty substances; considerably less, however, in lanolin. In the mean time, I am not so far advanced in my experiments with antiseptic lanolin that I feel justified in expressing myself concerning this for the time being.

*Thermic Disinfection.*—While cold is not able to destroy micro-organisms, but simply inhibits their growth, heat, on the contrary, is the best germicide. Practical application in surgery heat finds in the form of hot air, boiling water, and steam. *Hot air* is a much

more powerful disinfectant than chemicals, but it is considerably inferior to boiling water and steam. Koch and Wolfhügel have found that non-spore-bearing bacteria are destroyed in the course of an hour and a half, in hot air, at a temperature of 212° F., while spores require a temperature of at least 284° F., for three hours, for their destruction. To this disproportionately long time dry heat possesses but little penetrative power. It takes a very variable, and, at any rate, a very long time to bring the temperature up to the desired height in the articles to be sterilized, while, as a matter of experience, it is very difficult, not to say impossible, to obtain a uniform temperature in dry-heat sterilizers, for which reason the thermometer is not a safe guide. When to this is added that the dressings suffer materially in this continued and high temperature, that the instruments rust, lose in temper and edge, and that these sterilizers are both cumbersome and expensive, it is no exaggeration to maintain that sterilizers for hot air alone should only be of historic interest in surgery. However, there is one important material which seems to be most properly adapted for sterilization by hot air, viz., catgut, which, as is known, neither stands boiling water nor steam, and whose sterilization by chemical means so often has proven unsatisfactory, not to speak of the long time required. As catgut, because of its absorbability, more and more gains ground *pari passu* with the perfection of its sterilization, both as suturing and ligating material, and as I have long been of the decided opinion that the surgeon himself shall undertake or, in any case, control his asepsis, I have devised the sterilizer, which I later will demonstrate, to include also hot air, so that it can be utilized for catgut, which, so far as I can see, ought to have quite a future in military surgery, for the reason that it can be at hand in a very convenient form. Benckisser deserves the credit of having conceived the happy idea of sterilizing catgut by dry heat in double hermetically sealed envelopes—one within the other; since micro-organisms can not penetrate dry paper, the catgut will remain sterile indefinitely, if the envelopes are kept dry. This is, indeed, convenient. In this way we can carry sterile catgut in our pockets. When it is to be used, an assistant tears the outer envelope, which, of course, is infected on its outer side, while the surgeon himself, or his first assistant, removes the inner sterile covering which contains the catgut. Benckisser's idea has im-

pressed me so favorably that I long ago adopted it for all the catgut that I employ in my surgical practice, but with such modifications that I shall take the liberty to describe my procedure *in extenso*.

The raw catgut, which must be of prime quality in order to retain the necessary strength after exposure to a high and prolonged temperature, is simply cut up, without special preparation of the hands, into suitable lengths; the original bundle is divided so many times that each individual string measures, respectively, twenty or forty inches — two convenient lengths for practical use. Each of these strings is wound about two fingers in a coil, which then is wrapped up in wax-paper, and since the mercantile article is very thin and easily perforated by the free ends of the coil, the wax-paper is doubled, whereupon the whole is put in a small envelope which can be hermetically sealed, and upon which is marked the length and size. The catgut is placed as nearly as possible in the middle of the envelope, which is now ready for sterilization. When the required amount of envelopes are made up, they are arranged in a specially constructed tin box, whose bottom is perforated and whose cover is provided with a small funnel to admit easily the thermometer to the interior of the box (see illustration). The envelopes are set up edgewise, and must not be packed more tightly than will admit of free space between each one, to allow the free circulation of the hot air. According to the thickness of the envelope, which depends upon the size and length of the gut, the box will receive from 150 to 200. The catgut-box is now placed within the sterilizer; the pan is filled with cold water; the hood is applied without the cork; a thermometer, which registers up to 400° F., and short enough to be completely hidden inside the apparatus, is slipped in, so that the bulb rests upon the upper edge of the envelopes. The sterilizer is now put over the burner. For the sterilization of catgut it is important to employ a burner which can be regulated and which will not soot, since the last interferes with the raising of the temperature. We must use either a good gasoline or a gas burner, preferably with two regulating cocks. We begin with a very small flame, increasing it hour by hour until the temperature, at the end of three or four hours, is at the required point (about 284° F.). When this temperature is reached it is continued for at least three consecutive hours, after which the flame is turned off, and the catgut box

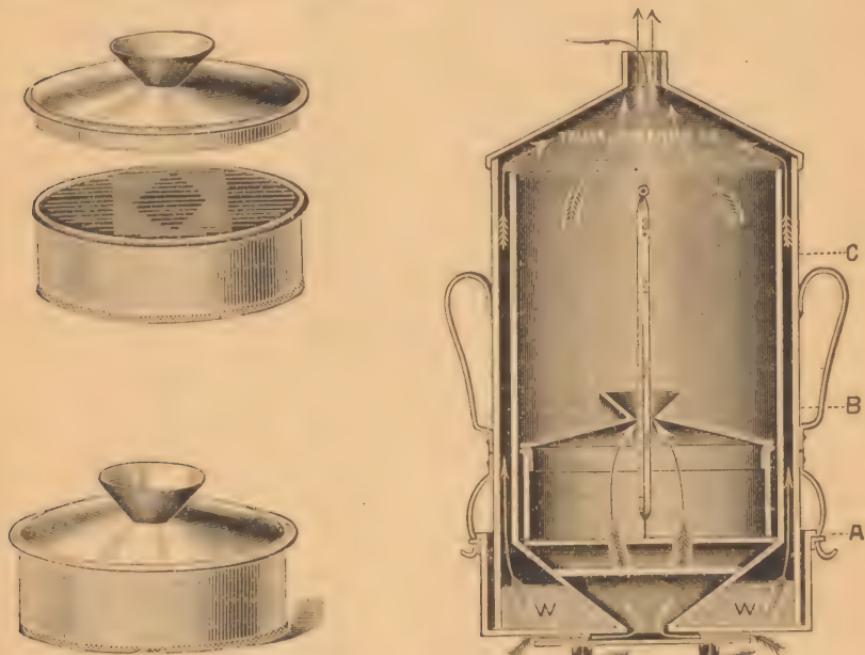
removed upon cooling — the whole procedure requiring at least six hours, three of which are consumed in the gradual heating up. As the original quantity of water — about one gallon — does not suffice for so many hours boiling, water must be added time after time; this takes place without interruption of the sterilization or name-worthy reduction of the temperature, as it is indifferent whether the water poured into the lip be warm or cold.

I have already mentioned that the thermometer must not extend beyond the apparatus. If it does, some of the vapor will be condensed on its projecting end, and run down along the thermometer to the bulb, which will be, to some extent, cooled off and register falsely. A loop is to be fastened to the upper end of the thermometer to allow, from time to time, its raising sufficient to read off and control the temperature. It is not difficult at all to keep the proper temperature, so much the more as it is not necessary, not even possible, to retain the temperature at exactly 284° F. It suffices that the temperatures does not descend below 280°, and preferably not above 300°, as higher degrees will burn the catgut; still, it can withstand a short exposure to 320° without being destroyed.

It is to be remembered that it takes time for dry heat to communicate its temperature to the envelopes and their contents, and that this communication does not keep pace with the gradual rise in the temperature of the hot air. We must bear in mind the little penetrating power of hot air, and that paper is a poor conductor of heat; consequently, it is wise to continue the sterilization fully four hours after the thermometer registers 280°, to be sure that the envelopes have had the benefit of at least three hours of this temperature, the time required for the complete destruction of the spores of anthrax.

When the envelopes are removed, after completed sterilization, we will observe that they have changed in color from white to yellow; that they are oily, especially pronounced immediately over the coil, and very slippery. The yellow color is most marked at the lower border of the envelopes; evidently the temperature has been higher at this point. This has also been the case, as is evidenced by a glance at the illustration below. The hot air in this apparatus enters from below; at the wire diaphragm, upon which the catgut-box rests, the temperature with good flame is 300° to 320° F.; the temperature sinks gradually higher up, so that it is only about 240°

in the upper part of the sterilizing chamber, because this, on all sides, is surrounded by steam at  $212^{\circ}$ , which, consequently, lowers the much higher temperature of the hot air. It is only in the lower two or three inches of the sterilizing chamber that the temperature can be raised to at least  $284^{\circ}$ ; this part is alone suitable for the scientific sterilization of catgut, for which reason the catgut-box is made but two inches high, and the envelopes a little less to allow for the flange of the cover.



The bottom of the box is perforated to admit of the entrance of the hot air. The temperature is taken at the upper border of the envelopes to make sure that the whole envelope is exposed to a temperature of not less than  $284^{\circ}$ . There is, as a rule, about  $20^{\circ}$  difference between the superior and inferior border of the envelopes; therefore, the color is more brown below, and for this reason I take the simple precaution to place the catgut coil in the middle of the envelope to insure against burning, and to secure the most possible uniform temperature. After a few trials of the apparatus, and a little experience in packing the envelopes uniformly, it is hardly necessary to

observe the thermometer, because we know how wide-open to leave the regulating cocks to obtain the desired temperature; patent gas regulators are superfluous. In order to provide for free circulation of hot air between the individual envelopes, especially at the location of the coils, arrange according to the illustration.

Cultures from catgut sterilized as above have, without exception, been found surgically sterile. Even the virulent spores of anthrax are destroyed, as is evidenced by the tubes here exhibited, while the pyogenic bacteria have succumbed long before— $212^{\circ}$  F., for  $1\frac{1}{2}$  hours, being sufficient, as stated above, and verified by numerous cultures of my own. However, bacteriologically, sterile catgut is not always achieved. At times, colonies of *hay-bacilli*, and their spores, are encountered. Happily, these micro-organisms are non-pathogenic, and their destruction entails also, generally, the destruction of the catgut. If you will kindly open some of these envelopes, which I sterilized a few days ago, you will be surprised to find that the individual strands apparently have lost nothing in strength from the high and continued temperature to which they have been exposed. Reverdin, who claims the honor of having been the first to suggest dry heat as the safest disinfectant for catgut, is of the opinion that the reason why it became so often brittle in dry heat was owing to its being burnt up in its own oil. This is not my experience. At times I do find, it is true, notable variation in the strength, not in the same, but in different boxes of catgut; but this can possibly be ascribed to the fat, since the temperature has been the same in all. I believe—which Benckisser, to my knowledge, first called attention to, and which Reverdin, also, in his last book, admits the importance of—that it is the water contained in the catgut which is the determining factor. If the catgut is heated too quickly, it will be literally boiled in its own water, and catgut does not stand boiling. The heating must be slow and gradual, so that the gut will be absolutely dry long before the boiling point is reached. This is, undoubtedly, the secret. If this is strictly complied with, we will invariably find, as a result, that the catgut is in prime condition as regards strength. If the catgut, in spite of this, proves brittle, we must not seek the cause in the contained fat, but in the quality of the catgut. I use, with great satisfaction, imported German catgut, marked 00-0-1-2-3, etc.; and I spare to the poor

kangaroo his costly tendons. Benckisser removes the fat in the catgut with ether; Reverdin employs catgut delivered fat-free from the factory; I, on the contrary, retain the fat, and even envelop the catgut in wax-paper, in order to add more to it. A part of the grease goes out into the envelope, which it makes oily and smooth, but a good deal remains in the catgut itself. I do not remove the fat of the gut, because I have found, what *my* ordinary sound mind could predict: first, that pure fat heated to a temperature of 284° F. could not diminish the strength of the catgut either more or less than hot air of the same temperature; second, the most important—that fat-containing catgut is a much less favorable culture medium for all pathogenic micro-organisms than fat-free; and lastly, that fat-containing catgut does not soften up and become absorbed as quickly as the fat-free. Even surgically, sterile catgut is not exempt from occasionally causing sepsis; this sounds paradoxical, but can occur when sterile catgut is used under circumstances which do not or can not insure perfect asepsis. An aseptic result demands not only sterile catgut, but, also, that everything brought in contact with it is likewise sterile—hands, instruments, solutions, towels; and last, but not least, the field of operation. Provided that the catgut has not been infected in handling, but that the site of operation, where the catgut is to be used, either as a suture, ligature, or both, is not aseptic, the catgut will form a good culture-soil for the bacteria present, upon whose number and virulence the successful resistance of the fat contained within the catgut depends, leaving out of consideration the more or less effective phagocytosis—which is equivalent to the degree of vascularity of the tissues and of their integrity, together with the general condition of the patient. In the skin, which, as already stated, only with great difficulty, if at all, can be rendered aseptic, sterile catgut, therefore, will be apt to produce stitch-abscesses; this applies especially where the skin is poor in vessels and under tension. We certainly can evade this complication by adopting Halsted's painless subcutaneous method of suturing, which commends itself as a timely procedure—thereby the bacteria of the skin and its adnexa are avoided. Those surgeons who do not feel inclined to adopt this mode of suturing, and who dread stitch-abscess, must consequently renounce the use of catgut as a skin suture, and reserve this ideal material for buried sutures and for

ligatures, provided they, like myself and many others, are fully convinced of its complete security for both purposes. Were catgut rendered not only aseptic, but antiseptic, what would then be the result? Should we not expect that such catgut would be a proper material for skin sutures? The answer has practically been given long ago. Catgut which has been sterilized by means of antiseptics—which is admitted can occur—will become, in spite of this, a favorable soil for bacteria present, as soon as the chemical is absorbed, and sepsis will occur. An old experience! Chemicals have not, up to date, solved the question of the applicability of catgut in skin sutures.

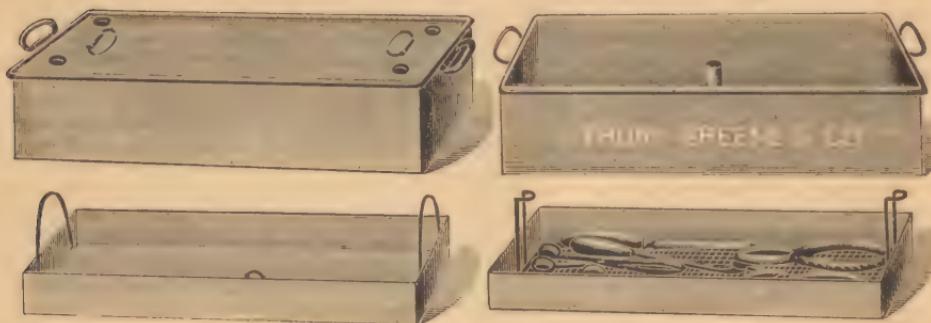
Very recently something has been written about catgut, which can be boiled after treatment with formalin, a forty-per-cent solution of formaldehyd (formol), a tanning agent of pronounced antiseptic properties. Thereby little is certainly accomplished. Formalin evaporates during boiling; the catgut, which the formalin converted into a sort of absorbable worm-gut, is sterilized like the last, only on the surface. Those micro-organisms not destroyed in the hardening with formalin—whose germicidal power in a given time is very feeble—are liberated as the catgut is absorbed from the, by the boiling water, non-affected interior. Consequently, I do not hope much from formalized catgut which can be boiled. Tanned catgut, either chromicized or formalized, has, however, an apparent advantage in being absorbed slowly. I, for my part, do not see any reason for using any other than the fat-containing sterile catgut which resists absorption sufficiently long. In order to preserve catgut as a skin-suture to the exclusion of all others, it will be necessary, so far as I am able to judge, to continue along the line indicated in retaining the fat, and to seek an agent which will render catgut an impossible culture medium, and remain with it until the last fiber is absorbed. Lanolinized catgut seems to be a step in advance, but the last word has not yet been said, for which reason I would provisionally recommend my catgut to you as a specially adapted all-around suturing and ligating material in military service.

Boiling water is an excellent germicide; it is excelled only by the free-flame, which has, however, but little practical application. Boiling water kills all surgical bacteria, spore-bearing or not, in the course of a minute or two. The pyogenic bacteria, according to Sternberg's world-famed tables, are destroyed in ten minutes by

moist heat at about  $150^{\circ}$  F., which corresponds to boiling for as many seconds. Moist heat is, consequently, disproportionately much more powerful than dry heat; the reason is not definitely settled. It is probably a purely mechanical boiling to pieces of the capsules of the bacteria. Boiling is such a safe, quick, easy, economical, and non-injurious method of sterilization, that it can not be too strongly advocated wherever it is applicable. Boiling is and will be our favorite method for the instruments. By making the water alkaline with soda or, still better, with green soap, its sterilizing power is increased, as the instruments are at the same time cleansed and the temperature somewhat increased; rusting is prevented, and the cutting edge of sharp instruments markedly little affected. The instruments must not be placed in the water before the latter boils, and it can not be too strongly emphasized that they should always be kept in first-class condition at all times. I know of no practical method of preserving instruments sterile and ready for use; if they are boiled and thoroughly cleaned after each operation, it will only be necessary to place them in a tray, and cover them with boiling water at the next operation, and they are perfectly safe after a few minutes standing.

Although the boiling of instruments can take place in any vessel whatever, it is desirable, especially on the field, to be supplied with a specially constructed instrument boiler; such an one is depicted on page 16. It is constructed on the principle of the steam sterilizer, illustrated further on, and consists of three separate parts—the boiler, the instrument tray, and the cover. The boiler is filled with sufficient water to cover instruments; some soda, green soap, or even lysol is added; the cover, formed like a pan and fitting inside the boiler, is adjusted as shown in the illustration; the apparatus is placed on the fire, while the instruments are arranged in the wire tray; when the water boils, visible at the border of the boiler, the latter is uncovered to receive the instruments. The central tube, which in no way interferes with the instruments, prevents the water from boiling over by conducting off the formed steam, which disappears invisibly under the bottom by passing over a hot plate, not shown in the drawing; the plate protects the flame from extinction by the steam. Five minutes boiling is all that is needed; the boiler is removed from the fire and placed on a stand, convenient

for the operation; the cover, which has been simultaneously sterilized, is lifted out and turned over; the instrument tray is deposited within the cover; the boiled water serves many purposes during the operation. I cherish the hope that this compact, transportable instrument boiler is eminently adapted for operations on the field.



*Steam.*—Water in a gaseous state follows closely boiling water in germicidal power when it has its temperature, when it is unmixed with air (saturated), when it penetrates the article to be sterilized, and when it condenses its moisture in every single particle thereof. If these precautions be observed, the articles concerned will literally be boiled in steam, resembling what occurs in boiling with water. Steam can, consequently, not cleanse anything; articles to be sterilized by steam must, therefore, be washed beforehand, if they are not clean. Steam is more particularly adapted to porous materials; solids are disinfected by steam solely on their surfaces; fluids are not sterilized by the steam itself, but by the heat communicated by the latter. In order to sterilize water, watery solutions, or emulsions, like milk, for instance, it is, therefore, perfectly indifferent whether the containing vessel is placed in steam, boiling water, or hot air.

Concerning the sterilization of fatty substances, it must be remembered that they can not derive the benefits of moist heat, because they either do not contain water, or, like lanolin, contain it in such a manner that it becomes separated. Consequently, the sterilization of fatty matters by steam means a dry-heat sterilization, ineffectual because of the low temperature.

Concerning the temperature of the steam, boiling water at the ordinary pressure of the atmosphere at the sea level gives off steam at  $212^{\circ}$  F.; this is *low* steam; the higher the altitude the less, consequently, the pressure and the lower the temperature of the boiling water and its steam. This must be borne in mind when sterilizing at high altitudes with steam or boiling water. Steam of a higher temperature than  $212^{\circ}$  is obtained by conducting it through heated pipes or into heated chambers (super-heated steam), or by evolving it under pressure—*high* steam. All pathogenic bacteria known, spore-forming or not, are destroyed in steam at  $212^{\circ}$  F. in the course of five minutes. Low steam is, therefore, as regards temperature, surgically perfect. Super-heated steam resembles hot air in germicidal power; its temperature must, consequently, be raised considerably, and it must be continued for hours in order to destroy spores. High steam, on the contrary, is more powerful than low steam. High steam at  $221^{\circ}$  will, in the course of ten minutes, kill all kinds of spores, pathogenic or not. No spores are capable of germinating when temperature of high steam of  $230^{\circ}$  F. is attained.

High steam is not only surgically, but bacteriologically, perfect. Where the temperature of low steam at high altitudes is below  $212^{\circ}$ , the sterilization must be continued beyond the above-mentioned five minutes, what we usually also do at lower-lying situations, where, for safety, we let the steam play for half an hour or more.

Concerning the penetration of the steam, we all know, by experience, how much more easily the steam penetrates than hot air. It is, in addition, a matter of fact that steam which streams from above downward penetrates to perfection every single particle of the porous materials in its path, because it, on account of its lower specific gravity than air, travels in a vertical column to a horizontal plane; while steam which streams from below upward (its natural course) preferably seeks an outlet along the line of least resistance with unequal distribution and uncertain penetration of the articles as a result. Streaming over-steam, which we might designate steam going from above downward, is, consequently, the proper steam, while streaming under-steam, which travels in the opposite direction, is absolutely to be discarded, in great as in small, when dealing with surgical sterilization of materials which are to be penetrated all through, unless these are uniformly packed—an unattainable

requirement in practical life, where the sterilizing chamber is filled with articles of most different sizes, form, and density, such as bandages, towels, sheets, cotton, etc., and which leave open spaces between them.

Steam at rest also penetrates well, particularly when it is high, though not as expeditiously and thoroughly as the incessantly streaming. Concerning the condensation of the steam, it is of considerable importance that the materials, to the greatest possible extent, get the benefit of the contained moisture of the steam; the more moist the steam operates, the more it imitates boiling and the better it sterilizes; condensation of the moisture is absolutely necessary, and will take place when the articles are of a lower temperature than the penetrating steam; the greater the difference the greater the condensation, and the more wet the articles. For this purpose the quantity of water delivering the steam cuts an important figure. The greater the quantity of water boiled the greater the amount of steam, and the more abundant the condensation. Therefore, steam-sterilizers should be constructed to hold a quantity of water proportional to the amount of articles and the size of the apparatus — half a gallon being appropriate for small sizes, and one gallon for larger. For the same purpose we must provide for good fire — preferably double non-sooting gas burners, powerful gasoline stoves, or a good kitchen fire. Alcohol or kerosene lamps are less suitable for larger sterilizers, while they can, with advantage, be employed for the small ones — for instance, milk sterilizers. Under abundant generation of steam the time of sterilization is shortened, the penetration and condensation following rapidly, and outweighs the additional time required in heating up a larger amount of water. The highest degree of condensation is attained by conducting abundantly generated steam through the coldest possible material. It takes the steam, of course, longer time to penetrate a cold than a warm article, as the first condenses more moisture than the last, and at a lower temperature, and as this condensed moisture must again be vaporized by the incoming steam to advance further. In order to abbreviate this time, it was formally recommended to construct steam sterilizers in such a manner that the contained articles could be heated by dry heat before the steam was turned on; this would, consequently, highly facilitate the penetration by reducing

the condensation, apparently saving time. Yet this heating up beforehand is largely a thing of the past; the time gained is lost in heating up the articles, and this is most weighty; we lose, to a great extent, the all-important advantages of an abundant condensation. It is a remarkable and at the same time a welcome circumstance, that the temperature, during condensation and the following vaporization of the condensed moisture, increases beyond the original temperature of the steam, and it rises higher the larger and more tightly packed the apparatus is—up to 218° F., and even more. The reason of this can provisionally be indifferent, it is enough for our purpose to point out this happy occurrence. This increased temperature lasts about one-fourth hour; when the condensation is complete, the condensed moisture again vaporizes and the steam flows unhindered and free, the temperature dropping to the normal. During the condensation and vaporization with their increased temperature, the determining and essential sterilization takes place; later on, the steam works with little or no moisture, and, therefore, with little efficacy, if with any at all. At any rate, the first fifteen minutes are more important than the same number of hours afterward. Concerning, finally, the saturation of steam, or freedom from admixture of air, all agree that it is of capital importance that all air contained in the sterilizing chamber must be completely expelled, so that the chamber can be filled with pure steam, as heated air has considerably less sterilizing power than steam. It looks very peculiar that modern German and American authors, who, in their books, take special pains to emphasize this point, without hesitation construct, picture, and recommend apparatus which in no wise comply with the laws they themselves have subscribed to.

It is an easy matter to expel the air completely from an apparatus constructed for streaming steam; the steam itself will effect this, provided it enters above and leaves below, since it, as above stated, is lighter than air, remains on top of this, and drives it out with a piston's action. If the steam enters below, it will hurry upward through the contained air and leave above; it will certainly carry with it a good deal of air, but never all of it, as the air is too heavy for it, and it has not the power, abundance, and uniformity. Under such circumstances, it is no criterion that every part of the steriliz-

ing chamber shows a uniform temperature of  $212^{\circ}$ , as the retained air will be heated to the temperature of the steam. We have then, in the same apparatus, air at  $212^{\circ}$  F. and steam at  $212^{\circ}$  F., and this justifies me with great positiveness to insist that surgical steam-sterilizers for under-steam are scientifically wrong and practically useless—at any rate, unreliable. We must vigorously demand that apparatus for streaming steam must be constructed for *over-steam*, whether they are large or small, stationary or portable. In apparatus for steam at rest, the air must also be expelled; this is attempted by the aid of a stop-cock on top, opened three or four times as the chamber becomes filled with high steam. The mass of steam is then so considerable, powerful, and compact that we reasonably expect to expel the air almost to completion, but not with the positive certainty as is the case with over-steam. After the above-laid-down principles for disinfection with steam, we arrive at the result that low, streaming, wet, saturated over-steam is surgically perfect, and that high, at best, wet, saturated steam is not only surgically, but also bacteriologically perfect. On either of these principles our surgical sterilizers must be constructed. The crucial question is, on what principle the most practical apparatus can be built. It is not very difficult to answer this question, when we consider that a sterilizer shall not only sterilize, but that it shall also deliver the sterilized articles perfectly dry. French authors, who are so clever to throw up to the faces of the German surgeons that they rely upon inferior apparatus, because they have adopted Lautenschlager's surgical sterilizer, while the Frenchmen employ Chamberland's bacteriological autoclave, forget that their sterilizers do not deliver dry materials, and that their results do not out-shine those of their German confrères. Chamberland's autoclave, for high steam, is viewed as a steam sterilizer—an ideal. Viewed from the standpoint of a surgeon, it is far from it. It must be compactly built to withstand the high pressure; this makes the apparatus expensive and unfit for transport. It is impossible on the field. The autoclave is intended to be a stationary apparatus. Provisions necessary to measure temperature and pressure, to make it tight, and to allow the escape of air and steam, complicate the otherwise simple construction, and increase the expense. And last, but not least, when sterilization is completed, after half to one hour, according to the size of the

apparatus, and the sterilized articles are removed, they are moist and must undergo an extra process to become dry and fit for use. Even if the autoclave, which, in my opinion, belongs in the laboratory only, can be recognized and adopted in large hospitals with great means and facilities at their command, it will be because of the above-stated reasons; at any rate, never be adapted to smaller hospitals, individual surgeons, and for the field.

Let us now, on the other hand, see how we can meet the designated requirements as regard sterilization, drying, transportation, and economy, in apparatus, constructed for over-steam. In the following illustration is pictured an apparatus, which has cost me much money and much costly time to bring down to that perfection and simplicity I claim to be its principal virtue.

My sterilizer consists of three essential parts: A basin (*A*, the water pan), an inner cylinder (*B*, the sterilizing chamber), and an outer cylinder (*C*, the hood). The basin and the inner cylinders form one piece, the outer cylinder another, and these two parts are, for transportation, held together by means of a clasp. The bottom of the basin is perforated by a circular opening, a good inch in diameter, corresponding to a similar one in the lower conical end of the inner cylinder; these two openings are seamed.

The diameter of the inner cylinder is one inch less than that of the basin, and the conical projection of the same begins at the level of the upper border of the basin, which is about three inches in height; at the junction of the inner cylinder and its cone is a wire diaphragm of galvanized iron; between this and the opening below there is a square tin plate. Under the bottom of the basin is



adjusted an iron plate, a quarter of an inch distant. The outer cylinder fits accurately within the basin; it is, consequently, a short half-inch distant from the inner cylinder, and extends half an inch above the latter; it ends, conically, above in a short tube, fully an inch in diameter, for the reception of a cork; it is provided with handles. The basin has a lip, for filling and emptying, not shown in the illustration.

*Directions for Use.*—Place articles to be steam-sterilized in the sterilizing chamber, tightly or loosely packed, as desired; adjust the hood, put in the cork, fill the water pan, and place the apparatus over any good flame. When the water boils the generated steam will ascend in the narrow space between both cylinders, and, as the cork prevents its escape above and the water its escape below, it must work its way through the sterilizing chamber and the contained articles, leaving by the lower opening after having driven out the air contained; here it meets the glowing plate, which converts it into invisible, super-heated steam. That lively generation of steam occurs, despite the fact that none is visible, we know beforehand can be ascertained by lifting the cork. During the boiling some steam is condensed by the outer cylinder on its inside; the steam condensed in the conical part of the outer cylinder will not continually drip down on the contained articles, because of this part's conical form, but will run back into the basin. After completed sterilization, which requires from one-quarter to one hour, according to the size of the apparatus and amount of packing, from the time the water boils, the steam contained in the articles must be expelled in order that it shall not moisten the contents when these are removed and cooled. This is accomplished by removing the cork, regardless whether the flame be turned off or not, or the apparatus removed. All steam, both that given off by the water and that contained within the sterilizing chamber and contents, will hasten to leave the apparatus through the upper opening, and it will not take many minutes before the steam is nearly all gone and the articles dry. The articles nearest the diaphragm are first dried, both because the steam first leaves them and because hot air enters the sterilizing chamber from below—to take the place of the departing steam. The iron plate under the bottom retains its heat for a long time, and the air, which must pass over it to enter the apparatus,

will be heated correspondingly. The uppermost layers will be dried last, since all the steam contained must pass through them; the close proximity of the steam generated from the water assists in keeping them slightly moist, but this can be remedied by emptying the water after completed sterilization.

Larger apparatus, which, by their weight, makes emptying difficult, are supplied with an extra cover for the inner cylinder to protect the contents from drip. During the drying, which is accomplished whether the apparatus is over the flame or not, the temperature of the articles drops considerably below that of the steam (down to  $170^{\circ}$  F. or still lower), despite that the inner cylinder is surrounded upon all sides by water and steam of  $212^{\circ}$  F., and despite that hot air of  $400^{\circ}$  F. enters the sterilizing chamber from below. This is the recompense for the increased temperature, which, as mentioned, occurs during the condensation and vaporization. As is made apparent, the sterilizer constructed by me, originally devised for steam sterilization, is likewise an apparatus adapted, not only for drying, but also for sterilization by hot air—the last being mentioned under catgut. If the apparatus be placed over the flame without a cork in the upper tube, the generated steam will leave the sterilizer through this. The inner cylinder will, consequently, be surrounded by water and steam at  $212^{\circ}$  F., while no moisture or steam enters its lumen. At the same time a draught is brought about in the inner cylinder in the direction from below upward, as in any vertically placed pipe; the air entering through the lower opening will consequently be heated by passing over the hot plate; the temperature of this hot air is about  $400^{\circ}$  F. at the moment it enters the apparatus. As this temperature is scorching, the above-named tin plate is placed in its path, midway between the opening and the diaphragm. This plate will absorb the heat and again irradiate it; acts, consequently, like a damper and at the same time an irradiator, with the result that the temperature at the level of the diaphragm will be about  $100^{\circ}$  lower, or  $300^{\circ}$  F.—a temperature which does not scorch; at any rate, not in the time concerned. Under sterilization of catgut is mentioned how this temperature is reduced gradually as we approach the top, as the inner cylinder itself is only at  $212^{\circ}$  F., the temperature of the surrounding steam, and thus acting refrigeratingly. In the upper part of the sterilizing chamber the

temperature of the hot air is about 240° F. The dry heat is subject to variations in the various apparatus; it is dependent, first of all, upon the strength of the flame; further, upon the thickness and size of the hot plate; upon its shape and its distance from the bottom of the basin; furthermore, upon the diameter of the lower opening of the sterilizer; upon the size of the tin plate; upon the size of the apparatus itself, etc.

I originally constructed my sterilizer for steam and for hot air combined, in order to dry steam-sterilized articles to a perfection not obtainable in any other apparatus, but when I found that it was possible also to control the dry heat, I devoted my attention to construct a special one for sterilizing catgut also, while I have not paid any special attention in that respect to those apparatus which are to be used for steam-sterilization and drying only.

I would be pleased if I have been so fortunate as to convince you that my sterilizer is not only surgically perfect in a scientific respect, but that it also practically possesses material advantages. The simple construction secures a reasonable price; there are no stop-cocks, regulators, or safety valves; a thermometer is superfluous, except for catgut; there are no solderings, which, by melting, if the sterilizer goes dry, renders it useless; everything is seamed. It is, consequently, durable, especially when made of copper, and it is at the same time light and transportable. If it falls and becomes

dented, it is the work of a minute to straighten it out. The change from steam to dry heat is simply effected through a cork, which is deposited in the lip of the basin when not in use. It is a matter, of course, that it has scientifically been tested and withstood the trial; practically, I never had any reason to suspect that it failed me. The model, which commends itself for use in the field, is illustrated opposite; it can be easily transported in a suitable wooden box.

It is deplorable that instruments can not be sterilized in steam without rusting; the steam can, unfortunately, not be rendered



alkaline. Catheart has certainly demonstrated that instruments do not rust in steam, when previously heated to  $212^{\circ}$  F. before the steam is turned on. I have tried this method extensively, and can verify the truth of Catheart's assertions, if we are very particular in heating, and do not allow the instruments to be cooled off in the sterilizer after sterilization, but I abandoned the procedure as soon as I realized that boiling was so much more simple, and when I suspected that it was more than dubious that the instruments were disinfected by this method. If the instruments are of the temperature of the steam admitted, no condensation will take place; the instruments will remain dry, and, consequently, unaffected both by moisture and by rust, despite that they are steamed. Instruments must be steamed while cold in order to be sterilized, and then they will rust.

It is, nowadays, fashionable to construct apparatus for combined boiling of instruments and steaming of dressings. I, myself, have long ago cherished the same thought, but have arrived at the conclusion that instruments and dressing should be sterilized separately. It is an easy matter to construct apparatus for combined sterilization, if we will employ under-steam, as Schimmelbusch and Beck have done, but I, for my part, will not agree to break with my own and, at the same time, universally recognized principles, for the sake of such an insignificant trifle. Both Schimmelbusch, Beck, and I have condemned under-steam upon principle, as it is mixed with air; besides this, the articles sterilized remain wet, as they can not be dried unless they are removed and shaken—a very unsurgical operation; and, as far as over-steam is concerned, I have, some time ago, in the "Medical Record," pictured an apparatus for combined boiling, steam, and dry heat, but I do not recommend it for instruments anyhow, as the boiling pan will require too great dimensions, so far as a transportable apparatus is concerned, when they are to be made circular in form, the most convenient for sterilizers.

In conclusion, a few words in regard to our dressings, which are particularly fitted for steam sterilization.

They can, in the course of half an hour, be made ready for use in a transportable or smaller apparatus. In military service it is, however, very desirable to have them ready without notice. I have

already demonstrated how we can always have ligatures and sutures at hand in sterilized form; I have not been able to do the same for the instruments, while Bloch has, happily, solved the question for the dressings. He has proposed to wrap them up in blotting paper, in double layer.

Blotting paper is impenetrable to micro-organisms as long as it remains dry, while steam penetrates it with ease. We arrange, therefore, the materials in small packages, and mark the quantity and quality upon the outside. These packages are placed in the sterilizer, steamed and dried in the ordinary manner. To protect against moisture, they should subsequently be placed in tin boxes. These packages remain aseptic as long as they are kept dry; if in doubt, they are given an additional sterilization. Anyone opens the outer blotting paper, while the surgeon, or his first assistant, takes the inner wrapper, which holds the dressings. I believe that Bloch's method is eminently adapted to military surgeons, who must exercise their important and responsible work under exceptional and difficult conditions.







